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XVII.—*The relationship of the water-supply, water-logging, and the distribution of Anopheles Mosquitos respectively, to the prevalence of Malaria north of Calcutta.*—By LEONARD ROGERS, M.D., M.R.C.P., I.M.S., Professor of Pathology, Medical College.

[ *With a Map.* ]

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The tract of country in which the present inquiry was carried out extends along the East bank of the Hooghly river from Calcutta to Naihati, a distance of 25 miles. The area is fairly typical of Lower Bengal, and has for a long time been looked on as water-logged and very malarious. In 1889 Dr. Gregg, then Sanitary Commissioner of Bengal, after a careful inspection, came to the conclusion that the unhealthiness was due to certain drainage channels having been silted up, and a scheme for re-excavating some of them was prepared, but has not yet been carried out. Owing to an unusual prevalence of fever in 1899 a further inquiry into the health of the tract was ordered, and was carried out by me in February last.

The plan of the enquiry was as follows. As the essential point to be determined was the proportion of the inhabitants of the various parts of the area who were suffering from malaria, a large number of persons were examined for enlargement of the spleen; its size being noted as either just felt, two fingers breadth below the ribs, four fingers breadth below, or extending beyond the navel. The spleen-count as a test for the degree of malaria in a tract of country was

used by Major Dyson in the Punjab in a similar inquiry, and by others, and is perhaps the most reliable and easily carried out method, especially in the season of the year when fever is at a minimum. Secondly, the level of the ground-water was taken in as many wells as possible, and inquiries were made as to the height to which the ground-water rose during the rainy season, so as to enable the degree of water-logging to be estimated. Thirdly, the drinking-water supply was carefully noted. Fourthly, the number of fever cases treated at various dispensaries month by month was compared with the monthly rainfall over a series of years, and worked out in charts, in order to ascertain the influence of seasons and rainfall on the fever rate. Lastly, some observations have been made on the distribution and monthly variations of the distribution of the *Anopheles* Mosquitos, which have furnished some rather surprising results.

In carrying out the spleen-count the whole area was divided up into thirteen Municipalities, and as far as possible 100 persons, about half of whom were children, were examined in each Ward of each Municipality, over 5,000 persons having been examined in all. As children suffer from enlarged spleen more commonly than adults, just as Koch has recently shown that the malarial organism is also found in a larger percentage of children, the figures have been corrected so as to represent the spleen rate of 50 children and 50 adults in each Ward, so that the figures of the different areas should be strictly comparable. Visits were made from house to house so as to get a fair sample of the actual inhabitants of the Wards, and every precaution was taken to obtain accurate results, every single person being examined by myself, a month being taken over the inquiry.

The results are embodied in the accompanying map, in which the different municipal areas are shaded in accordance with the percentage of persons who were found to have enlarged spleens, the darker areas representing the highest percentages and *vice versa*. The dotted lines within the municipal areas enclose the Wards or areas separately examined, and the large figures within them indicate the spleen percentage, while the figures enclosed in a circle are those of the distance of the ground water-level below the surface in feet and inches, the upper figures being the distance in the dry cold weather taken in the month of February, while the lower ones indicate the distance during the height of the previous rainy season. The small figures in brackets refer to the number of the Wards given in the left-hand margin of the map, and correspond with those in the tables given further on.

#### THE GENERAL RESULTS OF THE SPLEEN-COUNT.

The following table shows the percentage of people who were found

to be suffering from enlarged spleen in each Municipality. They are arranged in order from above downwards as they are situated on the map from north to south, while the westernly ones, which lie on the east bank of the Hooghly, are placed on the left, and the easternly ones, which are at a little distance from the river, are placed in the right-hand column, so that the table roughly represents their position on the map.

TABLE I.

Municipality.	Spleen percentages.	Municipality.	Spleen percentages.
Naihati ... ..	19.9	(Gobardanga) ... ..	(55.5)
Bhatpara ... ..	20.0		
Garulia ... ..	33.8		
North Barrackpore ...	36.5	(Basirhat) ... ..	(52.8)
Titagarh ... ..	37.8	Baraset ... ..	52.9
South Barrackpore (West)	25.2	South Barrackpore (East)	56.0
Kamarhati (West) ...	18.8	Kamarhati (East) ...	34.8
Baranagar ... ..	17.8	North Dum Dum ...	68.1
Chitpore-Cossipore ...	11.2	South Dum Dum ...	32.3
		Maniktolla ... ..	13.2
Average ... ..	24.5	Average ... ..	41.0

A glance at the above table or at the shaded map will show that the places situated on the bank of the Hooghly river have a much lower spleen percentage than those further to the east, even when the latter are but two miles from the river as in the case of the last five in the right-hand column of the table, with the exception of part of North Dum Dum. This having been ascertained, the question arose whether the lower rate on the banks of the Hooghly was to be regarded as the normal rate, and the higher figures of the inner tract as being due to water-logging or other abnormal conditions, or whether the latter must be taken as the usual state of affairs in this part of Lower Bengal, and the banks of the Hooghly as being exceptionally healthy. In order to solve this problem it was necessary to visit other places still further to the east, and Gobardanga and Basirhat, which are situated on the next flowing river to the east of the Hooghly, namely, the Ichahamati, were selected as the most suitable for the purpose. The former is some 20 miles to the east of Naihati, while the latter is 26 miles to the east of Baraset. The former is nearly surrounded by a bend of the river on two sides and by marsh land on the other sides, so that cannot be considered to be well situated from the health point of view, but Basirhat, on the other hand, would appear to be likely to be as healthy as any place in this portion of the Gangetic delta. Nevertheless, both show a spleen-rate of over 50 per cent., which, agreeing as it does with Dr. Gregg's statements about this tract of country, may be taken as

approximately the normal figure for this part of Lower Bengal. It would, therefore, appear that the east bank of the Hooghly is exceptionally healthy, although some of the Municipalities in the low-lying tract a little to the east of the river show very high spleen-rates, more especially North Dum Dum and the portion of South Barrackpore to the east of the railway, whose figures are 68 and 56 per cent. respectively. It may also be at once mentioned that last year, namely, 1899, was an exceptionally feverish one on account of the excess and uneven distribution of the rainfall.

On looking more closely at the figures it will be observed that there is one marked exception to the rule above pointed out, for Maniktolla, although situated away from the river-bank and on extremely low-lying and water-logged land, has, nevertheless, the second lowest spleen-rate; an exception which has proved to be the key to a very important factor in the causation of the variations of the spleen-rate in the tract under consideration. The only ground on which the low spleen-rate of Maniktolla can be accounted for is the enjoyment by this advanced Municipality of a good filtered water supply. It is also worthy of note that Chitpore-Cossipore, which has the lowest rate of all, namely, 11·2, has the double advantage of a filtered water supply and a situation on the east bank of the Hooghly. That these are the true reasons of its marked immunity is shown by the fact that the average rate of the two western Wards is only 7·4, while that of the two easterly Wards, situated from one to two miles from the river, is 14·7, that is almost the same as that of Maniktolla. The density of the population of Chitpore, and consequent smaller number of tanks, etc., may also be a slight factor in its healthiness, but the details to be given immediately with regard to the spleen-rates of different parts of Maniktolla and other places show that this is not a factor of any great importance, but on the other hand they will prove conclusively the intimate relationship between a filtered water-supply and a low spleen rate, but as this point is one of the utmost practical importance it will be necessary to go somewhat into detail with regard to the spleen-rates of different Wards of the same Municipalities, more especially of those parts of which are being supplied with good water by mills situated within their boundaries. At the same time the data with regard to the ground water-levels will be given, so that the question of water-logging can also be discussed.

WARD VARIATIONS IN THE SPLEEN-RATES. 1. MANIKTOLLA.—This Municipality, as will be evident from the accompanying map, is situated between the Circular and the New Cut Canals, and this area is so flat that there is only a fall of some eight feet from west to east in a distance of two miles. Its drainage is dependant on channels by the

sides of the four main roads, and is carried under the New Cut Canal by means of siphons into the Great Salt Water Lake, but these have to be closed at high tides to prevent the salt water running up into the drains, and they do not work very efficiently at present. The portion of the main drains in the western and more densely populated portion of the Municipality are brick-lined, but the eastern portions are of earth only. The water-level was taken in several wells, and in February it was found to average 5 feet from the surface of the ground, while evidence was obtained that it rises to within from one to two feet during the rainy season. A more typically water-logged place it would be difficult to find. For purposes of comparison it was divided up into western and eastern portions, and the spleen-rates were found to be 12·4 for the former and 14 for the latter, although it might have been expected that the less densely inhabited and more water-logged eastern portion would have had a decidedly higher rate. It was in the west part of this Municipality also in which the larvæ of the malarial-bearing mosquito was found in from half to two-thirds of the tanks as well as in some other pools, as will be detailed further on, so that none of the known causes of malaria were absent, in spite of which this Municipality, together with that of Chitpore and Cossipore, were the two which showed considerably the lowest spleen-rates of all the thirteen, and these two are the only ones which have a full filtered water supply.

The following table shows the above figures in a convenient form.

TABLE II.

## MANIKTOLLA.

Area.	Ground		Water-supply.	Corrected Spleen percentages.		
	Water-Level. Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
West part (1)	5 ft.	1 to 2 ft.	Filtered.	13	11·8	12·5
East	(2) 5 ft.	2 ft. 6 in.	do.	13	15·0	14·0

CHITPORE-COSSIPORE.—This Municipality is situated immediately to the north of Calcutta, and extends eastwards as far as the Eastern Bengal Railway and northwards to the southern border of Baranagar. It is divided into four Wards, namely, Chitpore and Cossipore West extending from the river to the Grand Trunk Road, the spleen percentages of which are 4·8 and 9·9 respectively; and Chitpore and Cossipore East, extending from the Grand Trunk Road to the Railway, and consequently distant from one to two miles from the river bank, the spleen-rates of which are 13 and 16·75 per cent. respectively. The whole area is supplied fully with filtered water, while those people who do not drink this (and they are certainly a decided minority)

will take chiefly river water in the western Wards, and tank water in the eastern ones. The water-level in three wells varied only between 4 and 5 feet from the surface in February, and in the rainy season it had been within from 1 to 2 feet of it; so that here again there was considerable water-logging but the minimum amount of fever, while although the western portion is more densely populated, the eastern part presents numerous tanks, and is generally favourable to the development of malaria, yet, apparently owing to the filtered water-supply, the spleen-rate is very low.

TABLE III.

## CHITPORE-COSSIPORE.

Area.	Ground		Water-supply.	Corrected		
	Water-Level.	Rains,		Spleen percentages.		
	Feb.,	1899.		Adult	Children.	General
	1900.			Males.		Total.
Chitpore, West (3)	4 ft. 3 in.	1 ft.	Filtered.	2.05	7.7	4.85
Cossipore, West (4)	4 ft. 9 in.	2 ft. 9 in.	do.	10.6	9.3	9.95
Chitpore, East (5)	5 ft. 1 in.	2 ft.	do.	16.0	10.0	13.00
Cossipore, East (6)	.....		do.	18.3	15.2	16.75

SOUTH DUM DUM.—To the east of the railway, which bounds the Chitpore-Cossipore Municipality, lies South Dum Dum, the most thickly inhabited portions of which are situated on the Jessore, Belgatia and Dum Dum roads, and it is divided into three Wards, which may roughly be taken as respectively including the parts adjoining these three roads. The inhabitants of Ward II who were examined mostly resided near the easternmost portion of the Dum Dum road, and the spleen rate was 37.9. Those of Ward I. mostly lived around that portion of the Jessore road which joins the eastern ends of the Belgachia and Dum Dum roads, and its spleen-rate was 45.3. Lastly, most of those examined in Ward III. lived around the western end of the Belgachia road just to the east of the railway, and consequently close to the Western Ward of Cossipore, and the spleen-rate among them was only 13.7, by far the lowest rate of any place to the east of the railway. Here again the probable explanation of this exception is that many of the inhabitants of this Ward obtain filtered water from the Cossipore Municipality as I ascertained both by inquiry and by seeing them carrying the water myself, while the portion of the other Wards which were examined were too far from Cossipore for the people to resort there for water to any extent. The conditions favourable to malaria are very similar in each Ward, for the Bajulla Khal flows right through Wards II. and III. as a broad swampy track with little or no current except during the rainy season, while the tide flows up it from the Salt Water Lakes at high water,

there being no sluice gate where it passes through the bund, while part of the houses of the Municipality are surrounded by rice fields. The water-level in a well in Ward I. was 8 ft. 9 in. below the surface in February, while during the previous rainy season it had risen within 9 inches of the ground, when the water could be dipped out by hand without the use of any rope, so that there is no doubt about this Municipality being very water-logged.

TABLE IV.

## SOUTH DUM DUM.

Ward.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
I. (7)	8 ft. 9 in.	1 ft.	Tank.	41·8	48·8	45·3
II. (8)	...	...	do.	35·4	40·4	37·9
III. (9)	...	...	Partly filtered.	11·8	15·6	13·7

BARANAGAR.—This Municipality lies between the Hooghly and the Eastern Bengal Railway, extending northwards for nearly two miles above Cossipore. It is divided into four Wards, the first three of which are between the river and the Grand Trunk Road, and the fourth lies to the east of the former, being mostly between the Grand Trunk Road and the railway, and consequently is dependant for its water-supply on tanks, while the first three get theirs mainly from the river, although Ward I., which is the most southernly bordering on Cossipore, obtains a certain amount of filtered water from that Municipality. Ward I. has the lowest spleen-rate, it being only 11·6, Wards II. and III. have intermediate rates of 14·3 and 18·1 respectively, while Ward IV. has the highest rate, namely, 26; differences which can only be explained by the varying water-supply, for although the last Ward also has a larger area under rice cultivation, that portion of it, whose inhabitants were examined, did not present materially different conditions from the other three Wards. Nor will the differences in the ground water-level, which are given in the Table below, account for those of the spleen-rates.

TABLE V.

## BARANAGAR.

Ward.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
I. (10)	7 ft. 7 in.	4 ft.	River and Tank & some filtered.	15·0	8·3	11·6
II. (11)	4 ft. 1 in.	2 ft.	River and Tank.	12·3	16·3	14·3
III. (12)	7 ft. 6 in.	3 ft.	do. do.	22·9	13·4	18·1
IV. (13)	...	...	Tank only.	14·6	37·3	26·0

KAMARHATI.—This Municipality lies immediately to the north of Baranagar, and consists of two Wards, namely, No. I. between the river and the Grand Trunk Road, and No. II. from the latter up to the Eastern Bengal Railway, and including Belguria. The spleen-rate of the river Ward was found to be 18·8, while that of the inland Ward was 34·8, a notable difference, while the first Ward mainly relies on the river for its water-supply, and the latter is dependant on tanks; for although there are a few wells in all the municipalities, mostly belonging to private individuals, yet they appear from my inquiries to be little if at all used by the people for drinking purposes, especially if filtered water is available, while many intelligent natives informed me that those who drank filtered water suffered much less than those who drank that from any other source, including well water. The ground water was 7 feet below the surface in February in the riverine Ward, and had been within 1 ft. 8 in. of it in the rainy season of 1899, while it was 1 foot further down in both seasons in the case of the eastern Ward, so that from this point of view the latter should have been slightly the more healthy of the two, instead of entirely the reverse obtaining.

TABLE VI.

## KAMARHATI.

Ward.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
I. (14) West	7 ft.	1 ft. 8 in.	River and Tank.	17·3	20·4	18·8
II. (15) East	8 ft.	2 ft. 8 in.	Tank only.	32·5	36·6	34·8

NORTH DUM DUM.—This Municipality is situated to the east of Kamarhati, and extends from the railway to Nowi Nadi, a distance of some four miles, and it consists for the most part of rice fields surrounding several villages. It contains two Wards, the westernly of which includes the large village of Nimta, while the easternly one includes Gouripur and Kadihati, which are situated on the Nowi Nadi, a sluggish stream which carries the surface drainage away to the south-east into the Kocho bhil. The water-level in a well in the western Ward was 7 ft. 3 in. below the surface in February, and had risen to within 2 ft. 3 in. in the rainy season of 1899, so that this part is certainly water-logged. The spleen-rate in the western Ward was no less than 76·6 per cent., while among 58 boys of the Nimta High School, who mostly belonged to well-to-do families, it was 67. In the eastern Ward the percentage worked out at 59·6, which is also very high, the average of the two Wards being 68·1; an extremely high figure. The water-supply is



solely from tanks and a very few wells, while the villages are surrounded by flooded rice fields during the rainy season; both a bad water-supply and water-logging being present and factors in causing the marked unhealthiness of this area.

TABLE VII.

## NORTH DUM DUM.

Ward.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
Western (16)	7 ft. 3 in.	2 ft. 3 in.	Tank	73·3	80·6	76·6
Eastern (17)	...	...	do.	56·6	62·5	59·6

SOUTH BARRACKPORE.—This Municipality is a very large and scattered one, mainly consisting of a riverine portion situated between the Hooghly and the Grand Trunk Road, the following four Wards of which (beginning from the south) were examined, namely; Agarpapa, with a spleen-rate of 30·8 and a ground water-level of 7 ft. in February and 1 ft. 8 in. below the surface in the rains of 1899: Punihati, with a spleen-rate of 31·25: Sukchar, with a spleen-rate of 12·1 and a ground water-level of 8 ft. in February, and 2 ft. below the surface in the rains of 1899: and Khardaha, situated just to the south of the khal of the same name, with a spleen-rate of 26·75 and a ground water-level of 6 ft. 6 in. down in February. All these depend mainly for their water-supply on the river, while the exceptionally low rate of Sukchar appears to be due to the unusual number of good pukka houses, many of which are two stories high, the inhabitants of which must have been much better to do than the majority of those in most of the other Wards, while tanks are also fewer than usual in this Ward.

This Municipality also includes a large area of rice land with scattered villages to the east of the Grand Trunk Road, and extending across the Eastern Bengal Railway. Two portions of this were examined, namely, one to the east of Punihati and Sukchar, consisting mainly of the village Sodepore on either side of the Eastern Bengal Railway, but mostly to the east of it, and another village called Natagore to the east of the former. The spleen-rate of this area was 60·4, that of Sodepore having been 61·7, and that of Natagore 64·4. The ground water-levels in February were 10 ft. 6 in. and 9 ft. respectively, and in the rainy season of 1899, 2 ft. and 4 ft. below the surface, measurements which, it will be observed, are very similar to those of the riverine portions of this Municipality, the slight difference being in favour of the inland portions, although their spleen-rates are very much higher than those of the parts on the banks of the

Hooghly, so that the water-levels do not help in explaining the difference. On the other hand, the dwellers near the river will mostly drink river water, while those who live more inland are entirely dependant on tank water. The other part of the South Barrackpore Municipality which was examined lies to the east of the railway opposite North Barrackpore, and consists of the villages of Chandanpukuria and Nona. The spleen-rate was found to be 51·6, while the ground water-level was 10 ft. 4 in. below the surface in February, but had risen to within 5 ft. during the rains of 1899, figures which are much more favourable than those of Maniktolla and Chitpore-Cossipore, which have the lowest spleen-rates. This, the most north-eastern Ward of the South Barrackpore Municipality, is also dependant on tank water for its drinking supply. The much lower spleen-rate, then, of the parts near the river, as compared with those at a distance of two miles or more from it, is again borne out by this Municipality, the figures of which are given in the table below.

TABLE VIII.  
SOUTH BARRACKPORE.

Area.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
Agarpara (18)	7 ft.	1 ft.	River and Tank	33·3	28·5	30·8
Punihati (19)	...	...	do. do.	20·0	42·5	31·2
Sukchar (20)	8 ft.	2 ft.	do. do.	19·3	6·9	12·1
Khardaha (21)	6 ft. 6 in.	...	do. do.	32·5	21·0	26·7
Sodepore (22)	9 ft.	4 ft.	Tank only.	50·0	70·9	60·4
Nona (23)	10 ft. 4 in.	5 ft.	do.	36·5	66·8	51·6

TITTAGHAR.—This is a small Municipality which lies on the east bank of the Hooghly between South and North Barrackpore, and is bounded on the south by the Khardaha Khal, and on the north by the Tittaghar Khal, and on the east by the Grand Trunk Road. It is divided into four Wards numbered I. to IV. from north to south. Two Mills in Wards II. and III. supply a limited amount of filtered water more especially to the inhabitants of Ward II., but Wards I. and IV. on either side of the other two drink nearly entirely river and tank water. Here, then, was a very good opportunity of putting to a crucial test the question as to whether filtered water drinkers suffer less from enlargement of the spleen than do those who drink other kinds, so notes were made regarding nearly all of the people examined in this Municipality as to what water they usually drunk, whether filtered, Hooghly, or tank.

The results are as follows, beginning from the south as before. Ward IV., which is a narrow strip situated on the north bank of the Khardaba Khal, up to which the tidal water flows as far as a sluice gate in a bridge under the Grand Trunk Road, and which contains a series of bustees, had a spleen-rate of 48 per cent., that is a high one for a riparian area. The water-level was 10 ft. 1 in. below the surface in February, but had risen to within 1 ft. 3 in. in the rains of 1899. Only 16 per cent. of those who were examined stated that they drank filtered water. In Ward III. 32 per cent. of those examined had drunk filtered water, and the spleen-rate was 30 per cent. The water-level had been 1 ft. 6 in. below the surface in the rains of 1899, and was 10 ft. 3 in. down in February, so that in this respect the conditions were just the same as in Ward IV., so this factor will not explain the considerable difference between the health of these two Wards; the water-supply only being different. Still more marked, however, was the difference between the spleen-rates of the two northern Wards, that of Ward III., which is opposite the Mills, being 19 per cent., and that of Ward IV. immediately further north, was 54.3; in spite of the ground water-level of the latter having been 6 ft. from the surface at the height of the rains of 1899, and 18 ft. 4 in. down in February last; an exceptionally low rate. On the other hand, the number of the people examined in Ward III. who had drunk filtered water was no less than 82.5 per cent., while only 19.6 of those of the Ward I. stated that they drank filtered water, and owing to their greater distance from the supply they were probably less regular in obtaining it than were the inhabitants of Ward II. at whose doors it was placed. These figures are sufficiently striking, especially as they confirm the data obtained in several other municipalities, to be given immediately, and they are also in entire agreement with the following results of the differences in the spleen-rate among the drinkers of the different kinds of water in this Municipality. Thus among 140 filtered water drinkers, 37, or 26.4 per cent., had enlarged spleens; while among 179 river water drinkers 74, or 41.3 per cent., were similarly affected; but of 55 tank water drinkers no less than 33, or 67.2 per cent., had enlargement of this organ. Further, if we take the degree of enlargement among the different classes as detailed in Table IX, below, we find that of those who had enlarged spleens the degree of enlargement was very slight in 62 per cent. of the filtered water drinkers, in 43.2 per cent. of the river water drinkers, but only in 27 of those who drank tank water, it being considerable or very enlarged in the remainder. Not only, then, is the percentage of enlarged organs much greater in those who drank unfiltered water (the percentage of mixed river and tank water drinkers being 47.4), but the degree of

enlargement of the organ was also much more marked in the latter classes as compared with the filtered water drinkers. (See Table X.).

TABLE IX.

## TITTAGARH.

Ward.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
IV. (24)	10 ft. 1 in.	1 ft. 3 in.	River and Tank.	36·0	60·0	48·0
III. (25)	10 ft. 6 in.	1 ft. 6 in.	do. but $\frac{1}{3}$ of them drank filtered water.	29·2	30·8	30·0
II. (26)	...	...	do. but 82% drank filtered water.	19·0	18·9	19·0
I. (27)	18 ft. 4 in.	6 ft.	River and tank water.	51·3	57·4	54·3

TABLE X.

## SPLEEN ENLARGEMENT AND WATER-SUPPLY IN TITTAGARH.

	Filtered water.	River water.	Tank water.	Total.
Spleen not enlarged	103·0	105·0	18·0	226·0
Spleen slightly enlarged.	23·0 (62%)	32·0 (43%)	10·0 (27%)	65·0
Spleen considerably enlarged.	9·0 (24%)	26·0 (36%)	15·0 (40·5%)	50·0
Spleen markedly enlarged.	5·0 (13%)	16·0 (21%)	12·0 (32·7%)	33·0
Total examined ...	140	179	55	374
Percentage with enlarged spleens.	26·4	41·3	67·2	39·5%

NORTH BARRACKPORE.—This is a small Municipality on the east bank of the Hooghly extending from the Tittagarh Khal on the south to the Ichapur Khal on the north, and bounded on the east by the Grand Trunk Road. It consists of three circles. Firstly, Monirampur, situated in the bend of the river to the west of Barrackpore Cantonment, the spleen-rate of which is 24 per cent., while the ground water is low, there having been no water in a well 8 ft. 8 inches deep in February. The water-supply is mainly derived from the river. Secondly, Nawabgung, also placed on the bank of the river to the north of the last

named, its spleen-rate being 28·6 per cent., while the water-level was 9 ft. below the surface of the ground in February, and had risen to 5 ft. from the ground in the rains of 1899. The water-supply is mainly derived from the river. Thirdly, Ichapur, which is situated to the north-east of the last circle, and the main portion of whose inhabitants reside at a distance of about one mile from the river, and near the Grand Trunk Road, and consequently are mainly dependant on tanks for their water-supply. The spleen-rate of this circle was 56 per cent., although as the ground water-level was 10 ft. from the surface in February and had not risen above 4 ft. in the rains of 1899 there was no difference in this respect from the other two circles which could possibly account for the greatly higher spleen-rate of Ichapur, whose water-supply from tanks instead of from the river appears to be the only possible explanation of the facts recorded.

TABLE XI.

## NORTH BARRACKPORE.

Area.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
Monirampur (28)	Below 9 ft.	...	Mainly river.	24·5	23·5	24·0
Nawabgung (29)	9 ft.	5 ft.	do.	37·2	30·1	28·6
Ichapur (30)	10 ft.	4 ft.	Tank.	52·0	66·0	56·0

GARULIA.—This small Municipality is situated between the Hooghly river and the Grand Trunk Road immediately to the north of the Ichapur Khal, and its northern half has been supplied with filtered water from the Dunbar Cotton Mill for the past two years, but the inhabitants of the southern portion for the most part still drink river and tank water. As there was a very general opinion among the people living near the Mill that they had suffered much less from fever since the filtered water had been introduced, I determined to examine 100 persons who resided near the Mill, and the great majority of whom (about 80 per cent.) were found on inquiry to have been drinking the filtered water; and another 100 a little further to the south, but all within one mile of the former, and who stated that they drank river or tank water. Among the former class the spleen-rate was found to be 21·1 per cent, while among the river and tank water drinkers it was 46·5 per cent., although the latter included 28 men who had arrived from the North-West Provinces only in November last, that is after the fever season is nearly over, and whose spleen-rate was only 10·7 per cent. If these men are excluded from the calculation, the spleen-rate of the permanent residents of this southern portion of the

Municipality] rises to 55·5 per cent., or just over two-and-a-half times as great as among the filtered water drinkers. A well in the northern part showed a water-level 9 ft. 6 inches below the surface of the ground in February, while it had risen to within 1 ft. 6 in. during the rains of 1899, so that there must have been a considerable degree of water-logging at that time, in spite of which the spleen-rate is low. These facts appear to admit of no other explanation than that the filtered water-supply was the cause of this low rate near the Mill as compared with a precisely similar area in other respects close by which had not the advantage of the stand-pipe water.

TABLE XII.

Area.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
	Northern part (31) (near Mill).	9 ft. 6 in.	1 ft. 9 in.	Filtered water.	17·7	24·6
Southern part (32)	...	...	River and tank water.	50·0	61·1	55·5

BHATPARA.—This Municipality consists of a narrow strip between the river Hooghly and the Eastern Bengal Railway and to the north of Garulia, and it is divided into three Wards, the northern two, Wards I. and II., of which, more particularly, and to a somewhat less extent the southern one, Ward III., obtain some filtered water from the Mills situated within this area. The spleen-rates of all are low, that of the southern one being slightly higher than the other two, although there is not much difference in their water levels, which are slightly in favour of Ward III. The figures are given in Table XIII. below.

TABLE XIII.

Ward.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
	III. (33)	10 ft. 3 in.	4 ft. 4 in.	Mainly river.	19·9	27·8
II. (34)	9 ft. 8 in.	5 ft.	River and filtered.	22·0	12·0	17·0
I. (35)	7 ft.	2 ft. 6 in.	do.	27·1	11·5	19·3

NAIHATI.—This Municipality is situated between the Hooghly and the Eastern Bengal Railway extending from Naihati itself northwards

for five miles as far as the Bhagar Khal, and although narrow to the south it gradually widens out to the north, so that while the lower three Wards are mainly inhabited near the banks of the river, the majority of the people in the two northern Wards live at some little distance from the river at Hali-shahar and Kanchrapara. Moreover, the Gauripur Jute Mills supply some filtered water to Wards II., so it is worthy of note that this Ward again has the lowest spleen-rate, namely, 10·8, which is little more than half that of the Wards I. and III. on either side of it, which are dependant on the river for their supply. Further, Wards IV. and V. have the highest rates of all, being mainly dependant on tank water for their supplies, so that, and that in spite of their ground water-level being lower than that of Ward III.; so that the only way in which these variations can be explained is by the differences in the water-supplies of the various Wards, which are also in accordance with the results obtained in every previously considered instance.

TABLE XIV.

## NAIHATI.

Ward.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
I. (36)	...	...	Mainly River.	16·6	22·5	19·5
II. (37)	...	...	Partly filtered.	6·6	15·0	10·8
III. (38)	7 ft. 9 in. 16 ft. 6 in.	... 8 ft.	Mainly River.	7·1	31·0	19·0
IV. (39)	10 ft. 3 in.	4 ft.	Mainly Tank.	15·3	29·4	22·3
V. (40)	10 ft. 3 in.	4 ft.	Tank.	13·3	42·5	27·9

BARASET.—This Municipality is situated on the Soonthee Nudi some eight miles east of the Hooghly river, and its surface drainage flows away to the south-east into the Kocho Bhil. The Soonthee was formerly a large river, but now it resembles an elongated swamp with little or no current except during the rainy season, while its bed is encroached upon in numerous places by series of tanks which in places leave but a few yards between them for the stream, and fishing weirs, etc., also obstruct its course. The Municipality is divided into five Wards, Nos. I. and II. including the town, while Nos. IV. and V. are to the east on the Soonthee Khal, and No. III. to the south. In all the spleen-rates are high, and the ground water-levels do not vary much, but are high in the rains, showing obstructed drainage and water-logging. The water-supply is from tanks, although one or two tube wells have been put down

TABLE XV.

## BARASET.

Ward.	Ground Water-Level.		Water-supply.	Corrected Spleen percentages.		
	Feb., 1900.	Rains, 1899.		Adult Males.	Children.	General Total.
I. & III. (41)	12 ft. 4 in.		Tank only	52.3	50.4	51.5
III. (42)	16 ft. 3 in.	4 ft.	do.	38.1	80.3	59.2
IV. (43)	8 ft. 2 in.	0 ft. 3 in.	do.	44.2	70.8	57.5
V. (44)	12 ft. 4 in.	4 ft.	do.	38.6	51.2	44.9

WATER-LOGGING AND THE RAILWAY.—It has already been pointed out in discussing the Ward variations of the spleen-rate that there is no definite relationship between the amount of malaria and the ground water-levels. Thus Maniktolla and Chitpore-Cossipore are the most water-logged parts of the whole area, yet they have the lowest spleen-rates on account of their filtered water-supply. The fact that the bank of the Hooghly river is slightly higher than the country further to the east, so that the surface water flows away from the river, and eventually finds its way back through khals to the river or runs off to the south into the Great Salt Water Lakes, might at first sight seem to indicate that the ground water-level would be lower near the river than it is further to the east. Measurements in the wells, however, do not bear this out, for there is very little difference in this respect in the water-level measured in wells on either side of the railway, while the differences noted were rather more frequently in favour of the eastern portions than the contrary. The differences in the spleen-rate, then, of the eastern and western parts cannot be explained on any theory of water-logging, while an examination of the whole area Ward by Ward shows no definite relationship between the spleen-rates and the height of the ground water-level, as a study of the Tables and Map will show.

The Eastern Bengal Railway, which runs from north to south through this area, and, together with the Grand Trunk Road, roughly divides it into western and eastern portions, has frequently been held responsible for the unhealthiness of the country, for it lies across the line of surface drainage. As, however, the drainage flows to the east if it were materially obstructed the western part should be the more unhealthy, instead of which precisely the opposite holds good. Moreover, in the few places in which wells were found on either side of the railway, although at some distance from it, there was no constant or marked difference between either the level of the ground-water in the dry season, or the height to which it rose during the rains on either side of the road and railway. There is, then, no



evidence that the health of this tract has been influenced by the railway or the Grand Trunk Road, and the spleen variations cannot possibly be attributed to their action.

#### DISTRIBUTION OF THE *Anopheles* MOSQUITOS.

It must now be taken as proved that malaria can be communicated to man by the bites of the *Anopheles* genus of mosquitos, which have previously bitten another case of malaria, and in whose body the plasmodium has undergone developmental changes. It still, however, remains to be proved that this is the only or even the most common way in which the disease is obtained, and it is worthy of note that Laveran, who was the first modern exponent of the mosquito theory, is still of the opinion that it will not explain all that is known of the etiology of the disease. Still enough is known to make it highly advisable to consider the question of the possibility of destroying the particular breed of mosquito which plays a part in distributing malaria. This should not be impossible in limited areas, at any rate, if Major Ross's statement as to their breeding-grounds is correct, namely, that they mainly breed in small pools which are not inhabited by fish, and yet are not so small that they will dry up in a few days, and consequently that such suitable pools are few and far between. In order to test this statement I searched for the larvæ in several Municipalities, but regret to say that I have not been able to confirm Ross's statements. On the contrary, I found the *Anopheles* larvæ in numerous tanks as well as in the small pools which Ross describes, and that too in spite of the former as well as some of the latter abounding in fish. This having been ascertained, a small portion of Maniktolla, measuring about one-sixteenth of a square mile, and containing some thirty tanks, was further examined. During the dry months of from February to May, which are the minimum fever months of the year, I found the *Anopheles* larvæ in from one-third to two-thirds of these tanks, often in enormous numbers, one of them for example, having been estimated to have contained several million larvæ on one day on which it was examined in May. In the earlier months especially they were also found in several small pools, but the numbers there were nothing as compared to those in the tanks, which are certainly the common breeding-ground of the *Anopheles* in the dry season at any rate. Three pools in a low-lying area are of interest, for in one, some two yards square, and a second which was five yards in diameter, fairly numerous *Anopheles* larvæ were found in spite of the presence of small fish in both, so that it is not surprising that they can also survive in tanks which are swarming with fish. Further, I failed to find any cases of fever near the infected tanks in the hot weather. As

there must be several hundred tanks in the five square miles of Manik-tolla alone, the chances of being able to destroy these larvæ appears to be very remote. Further observations are being made on the seasonal distribution of these larvæ and the amount of fever, but it may be mentioned that they nearly disappeared from the tanks after the first burst of the rains, and remained absent during a break which followed, although fever now began to be prevalent, so that up to the present the number of the *Anopheles* has been in inverse proportion to the amount of fever. Possibly the tank forms are different from those of the rainy season in the small pools, but I have not yet been able to settle this point. The differences will be only microscopical, so that this would not lessen the practical difficulties in lessening malaria in Bengal by destroying the mosquitos, the only possible way of partially affecting which would appear to lie in the time-honoured method of extensive drainage in order to lessen the number of suitable breeding-grounds for the mosquitos.

The great difficulty of destroying the *Anopheles* larvæ in Bengal enhances the importance of the influence of a filtered water-supply in reducing so materially the amount of fever, which has been shown to be the case in portions of this tract of country, while the much greater liability of the drinkers of tank water to malaria suggests that the disease may commonly be obtained by drinking infected water, as has for centuries been considered to be the case. Such a mode of infection may be easily reconciled with the mosquito theory if we allow that these insects, in addition to directly inoculating the disease, may also take the parasite back to water, perhaps by means of the black spores described by Ross, in which they may survive for a limited time only, so that the infection has frequently to be renewed by the mosquitos. This is a point which can only be settled by investigation, which I hope shortly to be able to undertake.

Lastly, an examination of charts showing the monthly rainfall and fever-rate in this tract of country revealed the fact there is no constant relationship between either the amount or monthly distribution of the rainfall of different years and the amount of malarial fever. A more detailed examination, however, showed that there is a relationship between the daily distribution of the rain and the fever; those years in which the rainfall is very irregularly distributed with frequent and prolonged breaks, being those in which malarial fevers are most prevalent. This point is also being more closely studied, in conjunction with the observations on the variations in the distribution of the *Anopheles*.

## CONCLUSIONS.

The general result of the inquiry has been to show that there is a marked difference between the health of the riverine and more inland portions of the area examined, the former being much more healthy than the latter. The comparatively healthy area extends from the river to the Grand Trunk Road, and in some parts to the Railway, a distance varying from one to two miles. No marked or constant differences in the ground water-level of the healthy and unhealthy parts has been found, which could possibly account for the differences in the spleen-rate noted, so that no theory of water-logging will explain them.

The most striking exception to the rule that the areas at a distance from the river bank have a high spleen-rate is that of Maniktolla, and the eastern portions of Chitpore-Cossipore between the Grand Trunk Road and the railway, both of which, together with the rest of the latter Municipality, have the lowest spleen-rates of all. Moreover they are also the most water-logged portions of the whole area, their ground water-levels both in the dry and in the rainy seasons being the highest met with, so that there must be some other factor to account for their marked immunity from malaria. This is certainly not the absence of the malaria-bearing mosquito, for it was in the first-named place that they were found to be more wide-spread during the minimum fever season than has hitherto been reported from any part of India. The only possible factor remaining is the water-supply, and it is noteworthy that these two water-logged Municipalities are the only ones which have a full filtered water-supply from the same source as Calcutta itself. That this good water-supply is the true explanation of their relative immunity from malaria is borne out by the very low spleen-rate of certain Wards of other Municipalities which have a partial filtered water-supply from various Mills, together with the low rates of the Wards of Baranagar and South Dum Dum, which border on Chitpore-Cossipore, from whose stand-pipes some of their inhabitants were obtaining filtered water, the details of which have already been given. Finally, the figures given in Table X. shows the spleen-rates among river water drinkers to be nearly double, and that of tank water drinkers to be nearly treble that of filtered water drinkers, strongly corroborate the evidence as to the benefit to be derived from filtered water, and affords a key to the whole distribution of the varying spleen-rates, as can be seen from a study of the accompanying map. Thus, Chitpore-Cossipore West, which has the double advantage of a filtered water-supply and close proximity to the river, so that those who do not drink filtered water will for the most part take river water, has the lowest rate of all, namely, 7.4. The eastern part of the same Municipality, which

has tank instead of river water as an alternative to the filtered supply, on the other hand, has a spleen-rate of 14·8, which is almost the same figure as that of Maniktolla, with a similar water-supply. Further, those Wards which are situated immediately on the river bank, but do not possess a filtered water-supply, and consequently get their supply mainly from the river, and to a less extent from tanks, have a rate intermediate between those with filtered water and the inland ones which are dependant entirely on tank water. In short, all the Ward variations in the spleen-rate of the whole area can be explained on the ground of their varying water-supplies in a manner which no other explanation will approach in completeness, so that it is impossible to come to any other conclusion than that the above is the true explanation of the facts recorded. Whether the *Anopheles* mosquitos play a part by taking the malarial parasite back to the tanks from their human hosts or not must be left to be determined by future experiments, but that a good water-supply is an important prophylactic measure in the lessening the prevalence of malaria must I think be admitted, and can be safely acted on.

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XVIII.—I. *Further Researches on Mercurous Nitrite and its Derivatives.*

II. *On Mercurous Iodide and a new Method of its Preparation.*—By

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- II. Mercurous Iodide: a new Method of its Preparation.

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(1)

PREPARATION OF MERCUROUS NITRITE ON A LARGE SCALE.

As the investigations I am about to describe involve the use of comparatively large quantities of mercurous nitrite at a time I shall